

## **PRODUCT-SERVICE SYSTEMS PERSPECTIVE FOR FRAMEWORK DEVELOPMENT FOR ASSESSING AND MEASURING SYSTEM MATURITY, SYSTEM READINESS AND CAPABILITY READINESS USING ARCHITECTURE FRAMEWORKS**

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### **ABSTRACT**

This study investigates the use of Product-Service Systems (PSS) perspective for refinement of the Conceptual Framework for Assessing and Measuring System Maturity, System Readiness and Capability Readiness using Architecture Frameworks. Metrics and measurement frameworks have no meaning if they are not used to make *decisions*. The importance of decision making at the architectural level is particularly pertinent for System Maturity

**Index Terms**—Product-Service Systems, Framework Assessment, System Maturity, System Readiness, Capability Readiness, Architecture Framework

### **1 INTRODUCTION**

Today's systems are inherently complex due to a number of reasons, such as software and systems integration between subsystems, systems of systems and networked systems of systems. This level of complexity introduces a number of challenges both during the system development programme and the overall lifecycle. This level of complexity also increases the risk in system development and system integration and implementation which is often reflected in delays in system development and/or system failure, including systems showing undeterministic behaviour once released into the real world even though they were considered to be "ready" for use (Tetlay 2010b).

During the development of a system, assessing the "maturity" of the system definition towards a successful outcome is important, as is the assessment of the "readiness" of a system to undertake roles within the real world context. Therefore, we need to be able to assess and measure, with confidence, a System's Maturity and Readiness within a development programme and overall lifecycle (Tetlay 2010b, Tetlay and John 2010 and Tetlay and John 2009a,b).

In (Tetlay and John 2009a), the authors discussed the relationship between Capability and Product-Service Systems (PSS) and the need for the assessment of Capability Readiness for PSS. They suggested that this assessment is essential to determine whether or not the elements of capability for PSS are in place and maintained for the successful delivery of a sustainable PSS.

Customer focus is shifting away from product features to benefits, which forms the basis of the notion of product-service systems. There is an increasing demand from customers for manufacturers to shift towards selling solutions and results instead of physical products to satisfy their needs. As a result of this change in customer demand, there is even greater emphasis on ensuring that the product-service systems have the "capability" of operating successfully in the real world to allow customers to purchase the solutions provided with confidence and at reduced risk. Manufacturers must be able to provide a system of products and services that are capable of satisfying customer needs (Tetlay and John 2009a).

Customers want to achieve the business benefits that a product, if utilised appropriately, enables rather than be interested in the features of the product. A product alone cannot provide these benefits. These benefits require many elements to be in place to achieve them. These elements are capability elements. An assessment of 'Capability Readiness' informs judgement of whether these elements are in place and is useful both at the outset and in ensuring the means to deliver the benefits are maintained. Therefore, providing a sustainable capability leading to a sustainable product-service system. This notion is useful in product-service systems which focuses on the sustainable delivery of a service linked to the achievement of business benefits (Tetlay and John 2009a).

The aim of the study presented in (Tetlay 2010b) was to develop a theoretical Framework for assessing and measuring System Maturity, System Readiness and Capability Readiness based on the research already undertaken by the authors (Tetlay and John 2010 and Tetlay and John 2009a,b). However, in (Tetlay 2010b), although the author did provide a conceptual Framework they were unable to define a possible method for assessment and measurement which was beyond the scope of the study. Therefore, this study is a continuation of (Tetlay 2010b) with the aim of refining the Framework by providing a potential *method* for the assessment and measurement of System Maturity, System Readiness and Capability Readiness from a Product-Service Systems (PSS) perspective using Architecture Frameworks. However, the results of this study should be used in conjunction with (Tetlay 2010a). According to (Blackburn and Valerdi 2009), metrics and measurement frameworks have no meaning if they are not used to make *decisions*. Therefore, the importance of decision making at the architectural level is therefore discussed in (Tetlay 2010a) which is particularly pertinent for System Maturity.

This paper is structured as follows. The first section provides background information regarding the conceptual Framework presented in (Tetlay 2010b). The second section outlines the methodology used for this study followed by the main sections of the paper. Finally, the conclusions are drawn and the next stages of the research are provided in terms of recommendations for further research.

## 2 BACKGROUND

In (Tetlay and John 2010), the authors introduced a new set of System Maturity Levels and a conceptual model for System Readiness and Capability Readiness, which were used as a basis for the conceptual Framework presented in (Tetlay 2010b) along with the findings from the case studies presented in the paper (Tetlay and John 2010). The authors also summarised the key characteristics of System Maturity, System Readiness and Capability Readiness as depicted in Table 1 (Tetlay 2010b).

With respect to the conceptual Framework for the assessment and measurement of System Maturity as shown in Figure 1, the left hand-side of the conceptual Framework focuses on the Design and Development (System Maturity Levels 0 to 3, inclusive) for the system or product being engineered and the right hand-side concentrates on achieving verification (System Maturity Levels 4 to 6, inclusive), i.e. System Maturity (Tetlay 2010b). The purpose of the conceptual Framework is to determine where you are in the System Development Lifecycle which determines the degree of System Maturity for the system or product currently being developed. The left hand-side of the System Development Lifecycle is less ‘mature’ than the right hand-side. Obviously, the further you are in the System Development Lifecycle, moving from the left to the right hand-side, the closer you are towards achieving a physical system or product and therefore achieving System Maturity (Tetlay 2010b).

Table 1: Characteristics of System Maturity, System Readiness and Capability Readiness

Characteristics of System Maturity, System Readiness and Capability Readiness

Concept	Scope	Solution	Operational Context	System Development Lifecycle	Verification and Validation (V-V)	Measures of Effectiveness (MoE) Perspective
Capability Readiness	Operational Capability (for the total-wider system or product, e.g. Product-Service Systems (PSS); System of Systems; Networked Systems of Systems, e.g. Networked Enabled Capability (NEC))	Independent (user perspective – extrinsic aspects of the system or product)	Explicitly Context Dependent (user perspective)	Capability Requirements	Capability Validation ('fitness-for-purpose')	Operational Effectiveness (the effect of the Capability Requirement for a given context, user perspective)
System Readiness	User Functionality (for the produced-engineered system or product)	Independent (user perspective – extrinsic aspects of the system or product)	Explicitly Context Dependent (user perspective, e.g. CONEMP)	User Requirements	System Validation ('fitness-for-purpose')	System Effectiveness (the effect of the User Requirement for a given context, user perspective)
System Maturity	Technical Solution (trying to bring a design concept into physical existence)	Dependent (SE perspective – intrinsic aspects of the system or product)	Implicitly Context Dependent (SE perspective - there is an underlying context, e.g. CONUSE)	System Requirements	System Verification (based on 'best practice procedures' and 'standards' in place)	Technical Effectiveness (the effect of the System Requirement for a given context, e.g. sub-system integration and interoperability, SE perspective)

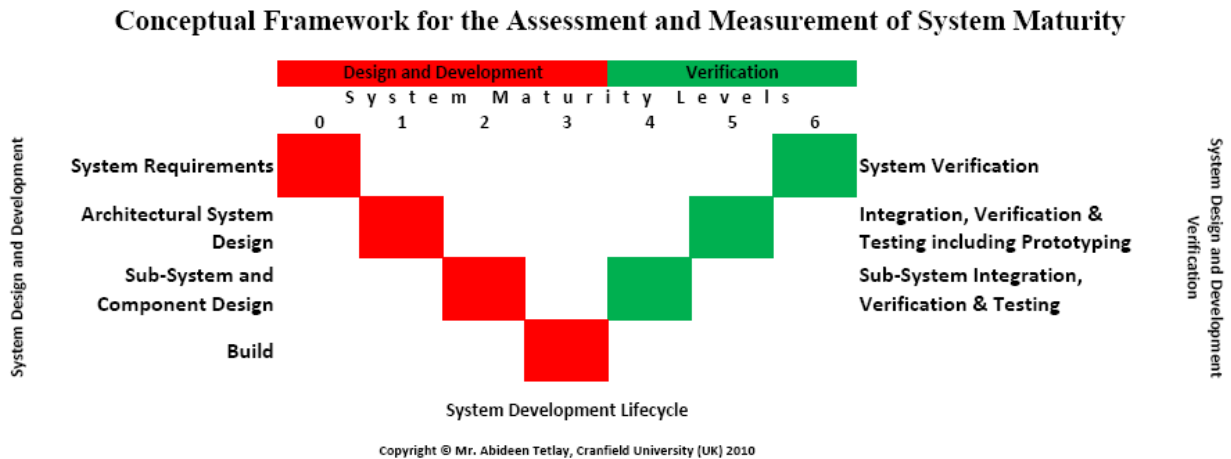


Figure 1: Conceptual Framework for the Assessment and Measurement of System Maturity

The main aim of the process for the assessment and measurement of System Maturity is to *verify* the System Requirements of a system or product being engineered in order to achieve System Maturity. The process should be used by system engineers and project managers to help monitor and communicate the progress of a system engineering project by assessing and measuring its System Maturity, feeding into the project planning and to enable the Systems Design Authority (SDA) and Systems Integrated Product Team (IPT) Lead to identify and address risks and mitigating actions in a consistent manner with confidence and at reduce risk (Tetlay 2010b).

With respect to the conceptual Framework for the assessment and measurement of System Readiness which is concerned with the extrinsic aspects of the produced-engineered system with respect to how the system is expected to behave in a particular context subject to certain enablers and barriers in place (Tetlay 2010b). An assessment is made for each operational context for the produced-engineered system taking into account the enablers and barriers currently in existence for that context. The degree of System Readiness is then determined and assessed as either achieving: ‘No System Readiness’ (NSR); ‘Initial System Readiness’ (ISR); or ‘Full System Readiness’ (FSR) and conceptually, the state of readiness can be thought of as being equal to either: ‘0’; ‘1’; or ‘2’, respectively (Tetlay 2010b). It is important to note that you first need to perform a System Maturity assessment and actually achieve System Maturity, i.e. the physical system must physically exist and be developed based on best practice procedures and standards in place and be fully mature and tested as mentioned in (Tetlay and John 2010) and before a System Readiness assessment can take place. The main aim of this process is to *validate* the User Requirements for a system being engineered in order to achieve System Readiness (Tetlay 2010b).

With respect to the conceptual Framework for the assessment and measurement of Capability Readiness which is also concerned with the extrinsic aspects of the system with respect to how the system is expected to behave, but in a ‘total-wider’ system for a particular context subject to certain Defence Lines of Development (DLoD) and enablers and barriers in place, rather than just focusing on the produced-engineered system for a particular context which is System Readiness. An assessment is made for each operational context for the system in question taking into account the DLoD and the enablers and barriers currently in existence for that context. An assessment for Capability Readiness will always take into account the DLoD in order to identify and mitigate risks across the DLoD. The degree of Capability Readiness is then determined and assessed as either achieving: ‘No Capability Readiness’ (NCR); ‘Initial Capability Readiness’ (ICR); or ‘Full Capability Readiness’ (FCR) and conceptually, the state of operational capability readiness can be thought of as being equal to either: ‘0’; ‘1’; or ‘2’, respectively (Tetlay 2010b). It is important to note that you first need to perform a System Readiness assessment and actually achieve System Readiness, i.e. the physical system must physically exist and be “ready” for use for a particular context, i.e. the ‘Fitness for Purpose’ question. Capability Readiness *extends* this notion of readiness and asks the question: Is the system ready for use as a part of a ‘total-wider’ system? The main aim of this process is to *validate* the Capability Requirements for a system operating in a ‘total-wider’ system in order to achieve Capability Readiness.

### 3 METHODOLOGY

The following two questions were specifically devised in relation to Figure 2 and subsequently used for the extensive Product-Service Systems (PSS) literature review which followed in order to provide answers to the questions:

- 1) What is the importance of the System of Systems perspective?
- 2) What is the relevance of the Product-Service Systems (PSS) perspective?

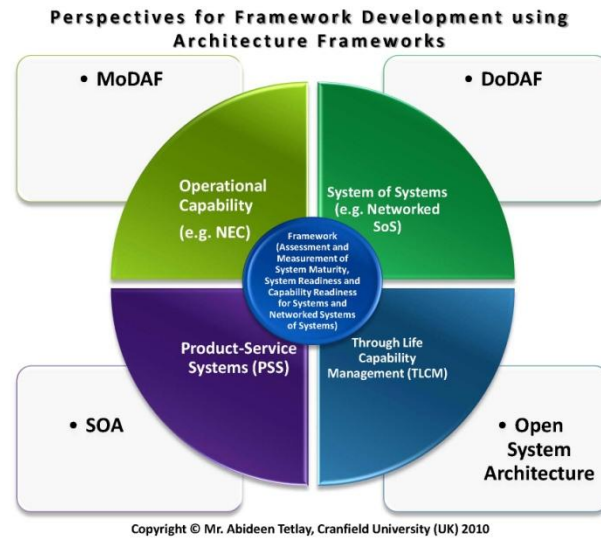


Figure 2: Perspectives for Framework Development using Architecture Frameworks

### 4 WHAT IS THE IMPORTANCE OF THE SYSTEM OF SYSTEMS PERSPECTIVE?

According to (Purewal and Yang et al. 2009), System of Systems (SoS) are large scale, distributed systems which are comprised of smaller complex systems (Kotov 1997). SoS is aiming to pursue the development, integration, interoperability and optimisation of systems to enhance performance (Pei 2000). The expectation is that SoS will improve effectiveness and enhance the ability to address complex mission requirements. The future vision is that SoS will incorporate numerous aircraft systems, ground vehicles, communications systems, ships and satellites as one large scale SoS (Fen et al., 2007). To draw the system boundary becomes considerably more complex and ambiguous for a System of Systems (Yue and Henshaw 2009). However, Networks of Systems of Systems are dynamic, large scale and subject to continual change. This is due to the need for availability and reliability in the short-term, the introduction of new equipment from various suppliers in the longer term and the need for interoperability with various coalition forces throughout (Russell et al., 2008). System level services describe systems in terms of the functional and non-functional properties and uses middleware to manage a loosely coupled Service-Oriented Architecture (SOA) (Russell et al., 2008). The United States Department of Defense Architecture Framework (DoDAF) version 1.5 (DoD 2007a,b,c) is transition to describe the NCW (MoD 2005) related aspects by changing the System view to System and Service view including some SOA parts and which is considered amending more by including the whole SOA issues (DoD 2007a) (Lei and Ai-min 2009). The US government has mandated that contractors express system architectures using the DoD Architecture Framework (DoDAF) to capture capability-driven requirements that are traceable to systems and functions and promote interoperability (Baumgarten 2008). The UK Ministry of Defense Architecture Framework (MoDAF) version 1.2 (MoDAF 2008) releases added Service-Oriented view and other views changed in order to archive the Network Centric Capability. Also, in order to emphasise on NATO Network-Enabled Capability (NNEC) (NEC), NATO Architecture Framework (NAF) version 3.0 (NATO 2007) adds the Service-Oriented view and has adopted SOA views as an integrated part (Lei and Ai-min 2009).

With respect to Framework development, (Tetlay 2010a) has strongly advocated the need to include the Quality of Service (QoS) attributes for any assessment and measurement of complex systems, including system of systems as well as for networked systems of systems. This is pertinent for the assessment of the non-functional traits of a

system (product) and for the maintainability of these traits in order to provide a sustainable level of capability leading to a sustainable level of service (Tetlay and John 2009a). For Software-Intensive Systems, the ISO/IEC Software Engineering Product Quality Standard Model could be used to derive the QoS attributes for the internal and external quality aspects of a system (Tetlay 2010a). However, the difficulty with non-functional attributes such as safety and security are that they are usually context and system specific and therefore difficult to generalise (Bosch, J., Bengtsson, P. O. 2001).

## 5 WHAT IS THE RELEVANCE OF THE PRODUCT-SERVICE SYSTEMS (PSS) PERSPECTIVE?

According to Russell et al., (2008), the use of service-oriented architecture has been motivated by many industries changing the focus from product delivery to service-based delivery. This is the notion of Product-Service Systems (PSS). The Service Oriented Architecture paradigm is concerned with the structure of service provision and consumption, and the infrastructure to support the interactions (Russell et al., 2008).

With respect to Framework development, in (Purewal and Yang et al. 2009) the authors stated that according to Bianco et al., (2007) they attempted to use *Architecture Trade-Off Analysis Method* (ATAM) (Barbacci, M. R. 2002) in another context apart from software systems, in *Service Oriented Architecture (SOA)* Bianco et al., (2007). They conclude that although there are no problems with implementation, concerns arise due to the size of *SOA* when compared to software code. ATAM provides a useful framework onto which further methods can be developed in other contexts. ATAM follows nine steps which include generating requirements and quality attributes, assessing the extent to which the *architecture model* meets the requirements and finally finding potential points of trade-off. This framework should be adopted when creating a quantitative assessment method. However, attributes such as safety and performance are context or even system specific and therefore difficult to generalise (Bosch, J., Bengtsson, P. O. 2001). Service oriented approaches offer a better basis for Networked-Enabled Capability (NEC) through the use of functional decomposition, defining connectivity boundaries between functions and allowing piecewise analysis of safety, security and performance. The piecewise approach allows the provision of systems to meet the dynamic needs of military capability, resilience to changes in short-term operation and the long-term evolution of systems. SOA provides a means to describe systems in terms of consumers and resources including how a consumer would use a resource and what quality attributes that resource should have. The NEC initiative recognises that offering functionality is the main requirement in supporting military capability, and that functionality can be delivered without ownership of the delivery mechanism (Russell et al., 2008). Attributes that describe the provision of a service include availability, security, cost and reliability. These non-functional qualities include measures of dependability (Avizienis, A. et al., 2004), such as availability, reliability and security. Other non-functional qualities can be specified such as price and payment terms (O'Sullivan, J. 2005) (Russell et al., 2008). In order to understand how to achieve service integration for military capability the work by Russell et al., 2008 investigates ways of evaluating capabilities composed of configurations of services using Measures of Effectiveness (MoE) (Sproles, N. 2000) as a basis for evaluating capability against scenarios, rather than attempting to evaluate specific architectures directly. The framework is an evaluation model providing MoE and Measures of Performance (MoP). MoP are used to validate implementations of service descriptions, whilst MoE are used to assess a configuration of services composed to satisfy a capability. MoE are applied using a composition of service descriptions and can therefore be applied at a conceptual level, independent of the services consumed. Measure of Effectiveness Layer – This layer utilizes a view of capability in the context of a scenario combined with an abstract definition of a capability defined by the integration layer. This means that conceptual configurations of services can be assessed independently of service implementations. This acts as a validation of the configuration against the given scenarios (Alberts, D. S. et al., 1999) (Russell et al., 2008).

## 6 CONCLUSIONS

This study has proposed a number of key recommendations to the conceptual Framework presented in (Tetlay, A. 2010b). This includes the use of Quality of Service (QoS) attributes to assess and measure the non-functional aspects of a system; *Architecture Trade-Off Analysis Method* (ATAM) for Service-Oriented Architecture (SOA) systems which is the preferred architecture for the design of Product-Service Systems; the piecewise approach which allows the provision of systems to meet the dynamic needs of military capability, resilience to changes in short-term operation and the long-term evolution of systems; and Measures of Effectiveness (MoE) and Measures of Performance (MoP) as a basis for evaluating capability against scenarios, rather than attempting to evaluate specific architectures directly.



## FURTHER RESEARCH

The next and final stage of the research is to ‘industrialise’ the Framework for practitioner use to make it ‘fit-for-purpose’ and user-friendly; through industry workshops in order to first refine the Framework for initial verification, as appropriate and for subsequent validation of the Framework for wider use and applicability. This is part of the on-going research.

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